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(71) Applicant
Otis Elevator Company

(Incorporated in USA–New Jersey)

Ten Farm Springs, Farmington, Connecticut 06032, United States of America

(72) Inventors
Ronald W Gagnon
John L Kettle
Francis J Yopak

(74) Agent and/or Address for Service
Frank B Dehn & Co,
Imperial House, 15–19 Kingsway, London WC2B 6UZ

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(54) **Escalator drive mechanism**

(57) An escalator includes a pair of pulleys (32, 34) that transmit a drive force to a double-sided toothed belt (14) which in turn transmits the drive force to a series of connected plastic links (16), each link being connected to an escalator step (18). The belt has a plurality of contoured teeth depending from each side of the belt, the length of one side of the belt engaging the contoured teeth of the pulleys (32, 34) and the teeth of the other side of the belt engaging the contoured teeth of the links (16). The plastics links are reinforced to withstand bending moments as the link transfers driving movement to the step.

FIG. 1

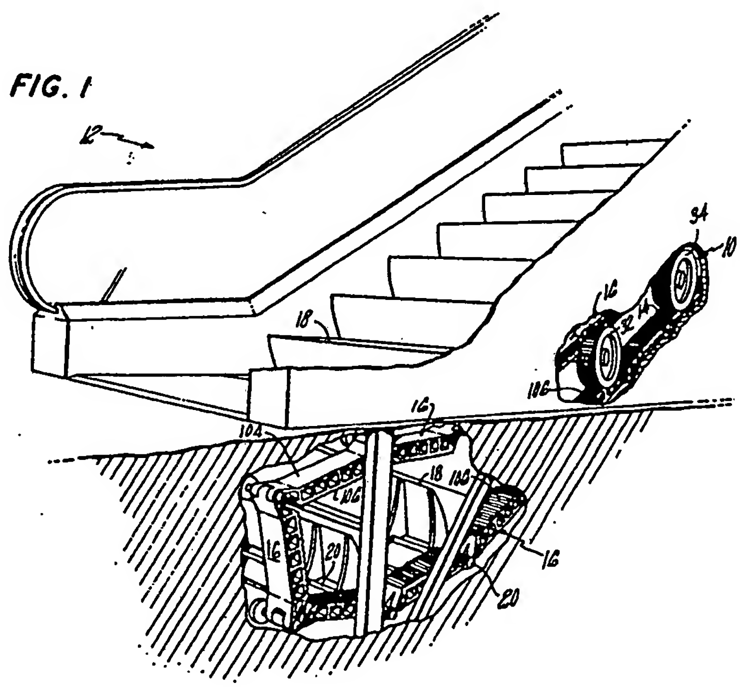

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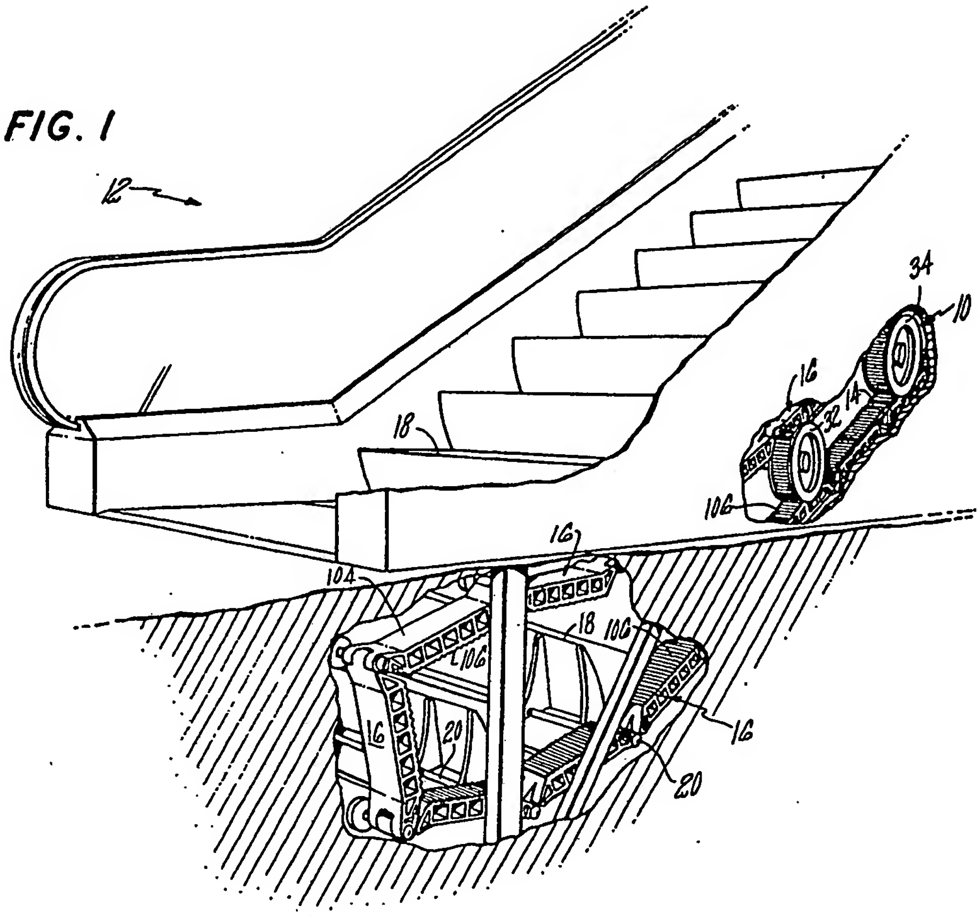
FIG. 1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34
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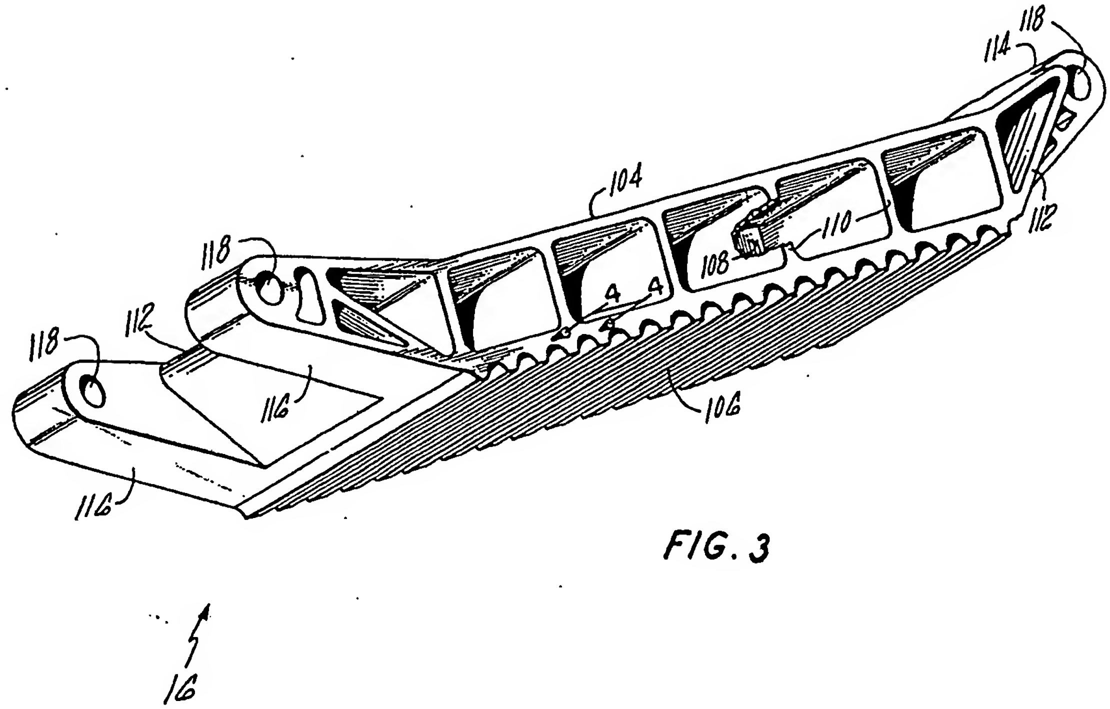
118
114
104
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4
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116
106
116
16

FIG. 3

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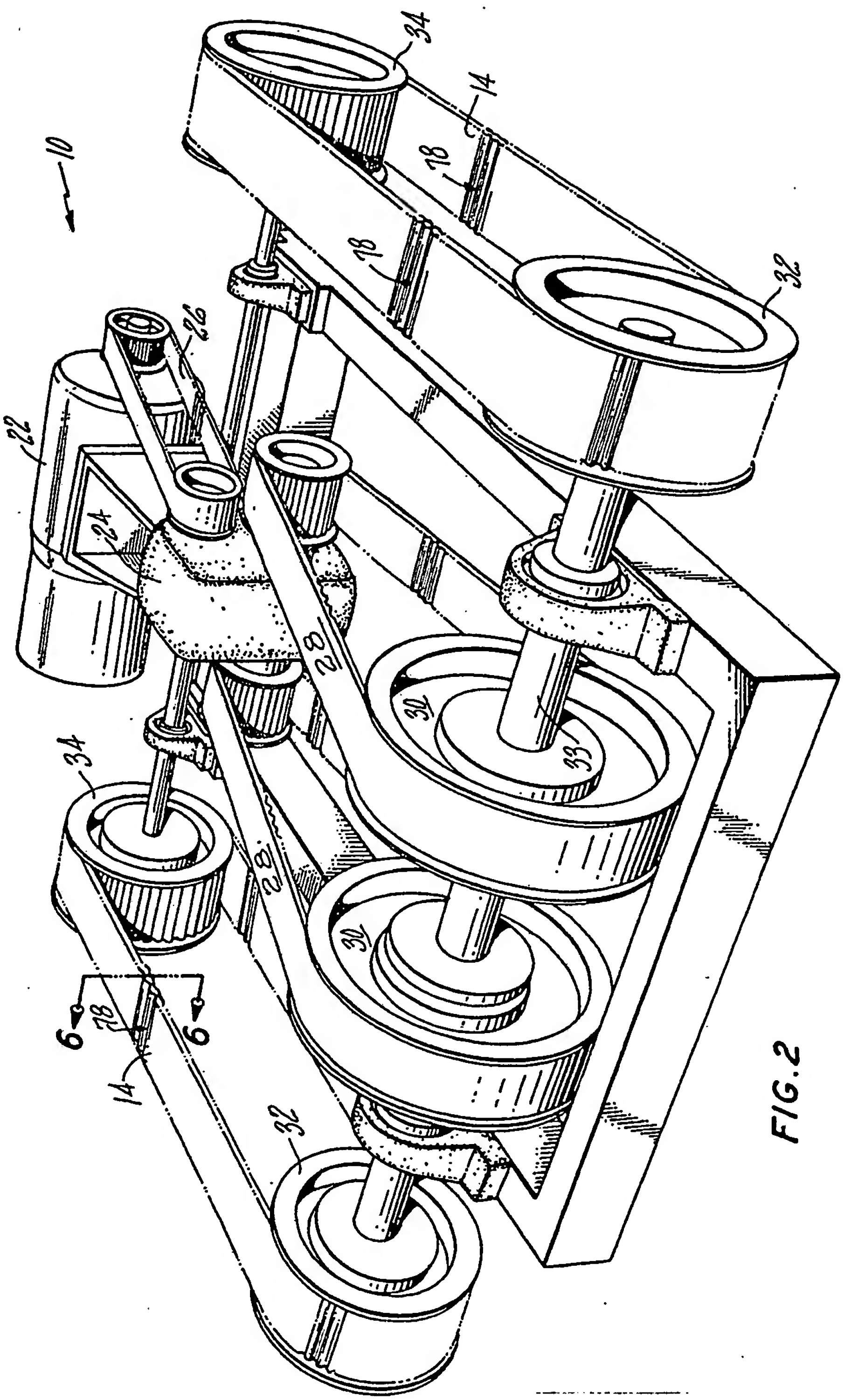

FIG.2

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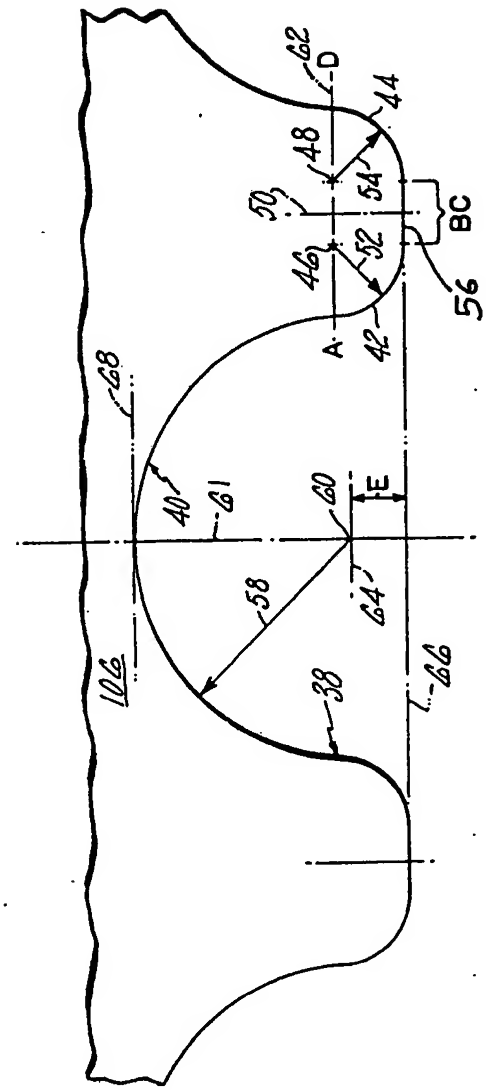

FIG. 4

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FIG. 5

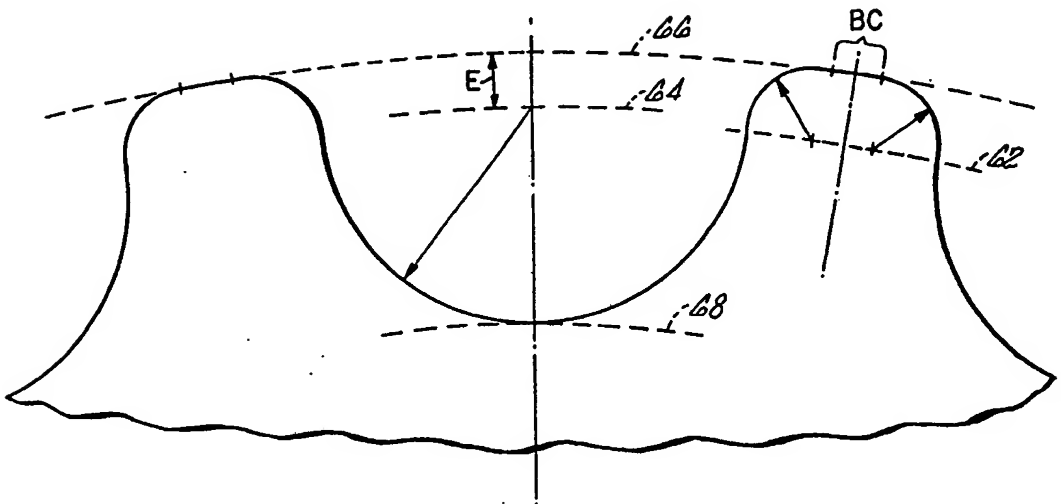
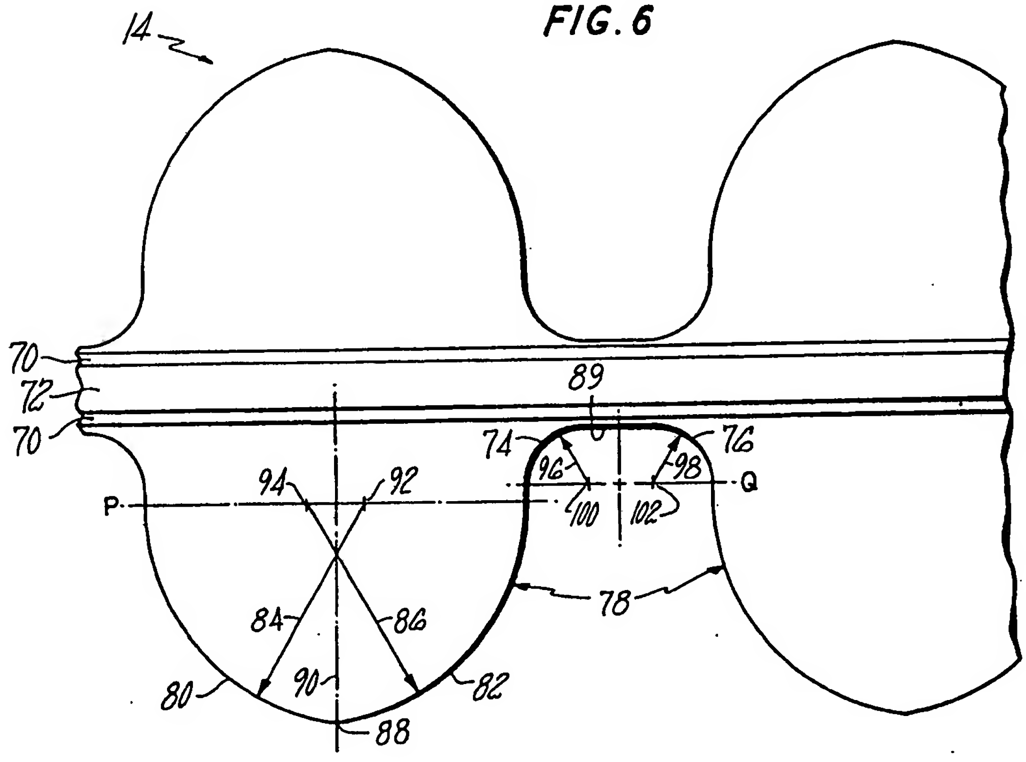


FIG. 6



SPECIFICATION

Escalator drive mechanism

This invention pertains to drive mechanisms for propelling escalator steps.

A vast majority of escalator systems currently in use contain escalator steps that are attached to a drive chain, which is propelled by a motor-driven sprocket at the upper terminal of the escalator.

Other escalators, some of which are in use, locate a drive, known as a modular drive, within an escalator rise. U.S. Patents 3,677,388 to Boltrek et al., and 4,361,220 to Kraft show such a drive. The drive consists of a loop of chain which engages a series of connected laminated metallic, toothed links, each link attaching to an escalator step. A number of the series of toothed links are driven by the upper and lower runs of the loop of chain. In Boltrek et al., the chain has a series of rollers of a resilient material to engage the link teeth. It was found in Kraft that it was advisable to provide metal rollers on either side or each resilient roller to increase chain life.

Other people-moving systems propel the pallets of a moving walk by means of a single-sided toothed belt. U.S. Patents 3,191,743 to Rissler et al., and 3,365,051 to Mullis et al., show people-moving walks. Mullis et al., in particular shows a modular drive having the upper and lower runs of a single-sided toothed belt driving a number of a series of connected metallic links, each link of the series attaching to a pallet. The belts of Mullis and Risler, however, experience more than two bends, some of which have a small radius, in transferring a driving force to the pallets. This bending of the belt, which is roughly analogous to continually bending a paper clip could lead to premature failure of the belt.

According to the invention there is provided an escalator having steps comprising:

a motor;

a pair of pulleys driven by said motor; each pulley having a plurality of juxtaposed contoured teeth;

a series of connected links, each link having a plurality of juxtaposed contoured teeth, each link connecting to one of said steps; and

a flexible, substantially inextensible tensile belt having a first side and a second side, each of the first and second sides having a plurality of juxtaposed contoured teeth, the teeth on said first side being in arcuate contact with said contoured teeth of said pulleys and the teeth on said second side being in linear contact with said contoured teeth of said links.

Preferably, the belt teeth are specially contoured to provide a uniform transfer of the driving force.

According to another preferred aspect of the invention, the teeth of pulleys, which impart the driving force to the belt, and the teeth of links, which transfer the driving force from the belt to the escalator steps, are contoured to cooperate with the contour of the double-sided belt such that the life of the double-sided belt is greatly extended.

According to another preferred aspect of the invention, the links are molded of a high strength, highly lubricious (i.e. does not require lubrication) plastic and are constructed to withstand a bending moment that is encountered as the link transfers the driving force from the belt to the escalator steps.

Advantages of a preferred embodiment of the present invention: long belt life and a smooth ride due to the cooperation among the contoured belt, pulley and link teeth; and a quiet ride and low maintenance requirements due to the cooperation between the elastomeric belt and plastic link.

Other features and advantages of the invention will be apparent from the specification and claims and from the accompanying drawings which illustrate a preferred embodiment of the invention wherein

Figure 1, a perspective view, partially in section, of a portion of an escalator, shows the modular drive unit of the invention in situ;

Figure 2, a perspective view, shows the details of the modular drive unit of Fig. 1;

Figure 3, a perspective view partially in section, shows the details of the toothed link of Fig. 1;

Figure 4, a partial longitudinal cross-sectional view along the line 4–4 in Fig. 3, shows the details of the links of Fig. 3;

Figure 5, a partial view, shows the details of the contoured pulley teeth of Fig. 2; and

Figure 6, a partial view, along the line 6–6 in Fig. 2 shows the details of the double-sided toothed belt of Fig. 2.

A modular drive unit 10 disposed within the rise of an escalator 12 and empolying the concepts of the present invention is illustrated in Fig. 1. The drive unit transmits a drive force via a double-sided, elastomeric, substantially inextensible, tensile belt 14 to a series of connected toothed links 16, each link in turn being connected to an escalator step 18 via an axle 20 to transmit the drive force to each step thereby moving the escalator steps.

Referring to Fig. 2, the modular drive unit 10 is shown having a motor 22 which transmits its driving force to a transmission 24 by means of a single-sided toothed belt 26. The transmission in turn transmits the driving force by means of a pair of single-sided toothed belts 28, at a rate calculated to safely drive the escalator, to a pair of drive wheels 30 which in turn transmit the drive force to a pair of first large diameter drive pulleys 32 via a connecting axle 33. The drive pulleys are each connected to a second large

diameter pulley 34 by the double-sided belts 14, as will be described infra, for the transmission of the drive force along the longitudinal stretch of belt between the first and second pulleys to the toothed links 16 and to the escalator steps 10 (see Fig. 1).

The toothed links 16 (see Fig. 3) are designed to transmit the drive force from the belt 14 to each escalator step via an axle 20. Each toothed link has an upper rectangular plate 104, a toothed lower rectangular plate 106 adapted to mesh with the teeth on the double-sided belt, and a rectangular spine 108 running the length of the link, orthogonally to, and connecting the upper and lower plate. A plurality of webs 110 are arranged orthogonally to the upper and lower plate and orthogonally to the central spine at both sides thereof to reinforce the body of the toothed link. The link must be reinforced to withstand a bending moment encountered by the link as the link transfers a drive force from the double-sided belt to the steps because the double-sided belts and the step axles are on different planes. A triangular buttressing portion 112 is attached to both ends of the toothed link at an angle of approximately 35° to the orientation of the plane of the upper plate to transfer the driving force from the double-sided belts to the step axles for a typical application. Extending from one buttress is a tenon-like tongue 114 at an angle of about 19° for a typical application. A pair of mortise-like arms similarly extend from the other buttress 116 at an angle of about 19°. Each tongue fits within the arms of an adjacent toothed link to form a connected series of toothed links (see Fig. 1). The angle of the buttress, the tongue and the arms allows the series of links to rotate around the upper (see Fig. 1) and the lower terminal of the escalator rise without the adjacent ends of the links colliding. Each tongue and each arm is provided with a bearing hole 118 to receive a step axle 20 that joins a toothed link tongue between an adjacent pair of arms and attaches each link to an escalator step to transmit the drive force from the belt to the toothed link series and to each step. The angle of the buttresses, the tongue, and the arms depends on the chosen length of each tooth, the width of the belt teeth, the number of links rotating about the upper and lower terminal of the rise, and the distance between the belt and the step axles to ensure that the belt teeth mesh with the link teeth.

The link may be constructed of Valox™ an aromatic polyester manufactured by the General Electric Company having the following characteristics; high dimensional stability, high lubricity (i.e. does not require lubrication), high chemical resistance, low moisture absorption and high heat resistance. Since each link does not require lubrication and the belt 14 is elastomeric, the necessity of lubricating the drive is eliminated, thereby reducing required maintenance.

Heretofore, plastics have not been known for use as links in escalators. It was thought that the links could not withstand the high bending moments experienced in transferring the driving force from the double-sided belts 14 to the steps 18 via axles 20. By providing the links 16 with the above noted construction (supra), the links withstand the encountered bending moment. The plastic links reduce the weight of the escalator considerably allowing a typical escalator having a six meter rise to downsize its motor 22 from fifteen to seven and one-half horsepower engendering lower capital and operating costs. Construction of the plastic links is far simpler and less expensive than metallic links. The plastic link requires the molding of the link as one complete part. Metallic links (not shown) require the machining of a metallic laminate, the bonding of a series of laminates, and the insertion of bearing inserts.

Each toothed lower rectangular plate has a plurality of curvilinear teeth 38 depending therefrom separated by curvilinear cavities 40. As seen in Fig. 4, each tooth tip, viewed in longitudinal cross section, has an outer configuration which is comprised of two circular arcs 42 and 44 having displaced centers of curvature 46 and 48 displaced from a tooth tip centerline 50. Arcs 42 and 44 have two equal radii 52 and 54 with centers of curvature 46 and 48 displaced equal amounts on opposite side of centerline 50 of the tooth 38 but on the same side of corresponding arcs. Both centers of curvature are within the link tooth. The nonintersecting arcs 42 and 44 are connected by a line segment 56. The arc 42 extends from point A to point B, the arc 44 extends from point C to point D. The centers 46 and 48 lie at equal distances from a tangent to the outside of the link at the centerline 50 of the tooth, i.e., lie at equal distances to opposite sides of the centerline 50 and lie at equal distances from the lower rectangular plate. The line segment 56 is a straight line parallel to the lower rectangular plate. The depth of the groove between the adjacent link teeth is less than the depth of a tooth of the belt which will be described infra. It is preferred that the link groove depth be between 1% and 15% less than a belt tooth depth. It is also preferred that the surface contact ratio of the belt tooth width, as will be described infra, to the length of the line segment 56 (the width represented by the length of the line B C in Fig. 2) be between 20:1 and 1:1 and desirably between 15:1 and 3:1.

The cross-sectional configuration of cavity 40 has a radius 58 much larger than radii 52 and 54 and has a center 60 which is above the lower rectangulr plate 106 and is on a centerline 61. The centers of radii 46, 48 and

lines 62 and 64 which are parallel to a line 66 within the outermost lying segments 56 of the tooth tips. The lines 62 and 64 are spaced inwardly from this line 66 a distance equal to or less than 30% of the total tooth depth. The total tooth depth is a distance between the intersection of line segment 56 and centerline 61, and a line 68 connecting the innermost points of cavity 40. The innermost point of cavity 40 is at the intersection of the arc generated by the radius 58 and the centerline 61.

The cavity 40 is formed by an arc of a circle having a radius 58 drawn from a center 60 on centerline 61. The arc forming cavity 58 may intersect the arc 42 on one side of the overall link groove profile and intersect arc 44 on the otherside of the profile. The profile of the link groove from the intersection of line segment 56 and centerline 50 to a corresponding intersection of the next adjacent tooth is repeated along the length of the link to define the other teeth and grooves.

The total depth of the link groove is equal to the distance measured along centerline 61 between the intersections of lines 66 and 68. The total depth of the link groove is the sum of the length of the radius 58 and the distance E. Preferably, the total depth of the link groove is not more than 15% less than the depth of the belt tooth which engages with the link groove. Consequently, the belt tooth may be in compressive engagement with the cavity 40. The length of the line segment is from 5%–100% of the width of the belt tooth on the belt with which the pulley is to be used, which will be described infra, and preferably between 6% and 33% of the width of the belt tooth. The depth of the link groove in conjunction with the shape of the link teeth acts to reduce the land wear, i.e., the abrasion of a belt protective layer and exposure of a belt tensile member by action of the link tooth against the belt. The land wear leads to premature failure due to a detachment of the belt teeth from the tensile member and/or a break in the tensile member.

The pulleys, as described in U.S. Patent 4,403,979 to Wujick which is herein incorporated by reference, are designed to provide efficient power transmission from the pulleys to the belt fitting within the pulley grooves while providing for extended belt life.

The circumference of each pulley has teeth shaped similarly to the shape of the teeth in the link as described above. However, the segments BC, the circles 62, 64 and the lines 66 and 68 of the link as shown in Fig. 3 and as adapted for the teeth of the pulley are arranged circumferentially (see Fig. 5). The pulley teeth are identicle to the link teeth except that the pulley teeth are arranged about the periphery of each pulley and the link teeth are arranged linearly along the rectangular plate 106. Both the drive and driven pulley are flanged (not shown) to prevent the lateral displacement of the belt when the pulleys rotate. The two pulleys reduce the number of bends experienced by the belt during operation to extend the life of the belt.

A double-sided belt, having contoured teeth as described in U.S. Patent 3,756,091 to Miller which is herein incorporated by reference, is used to transmit drive force from the aforementioned pulleys to the toothed links. The pulleys, as described supra in Wojick, are specially designed to mesh with the belt teeth as described in Miller. It was found that the belt of Miller increases the horse power capacity of a toothed belt to allow the belt to propel an escalator without experiencing the associated problem of tooth shear by obtaining a more uniform transfer of load from the belt tooth to a belt tensile member underlying the teeth. Referring to Fig. 6, a pair of substantially inextensible tensile members 70 are embedded on either side of a belt backing member 72 approximately at the roots 74 and 76 of the teeth 78. The substantially inextensible members reduce the problem of belt stretching which may cause link misalignment, noise, and breakage (a particular problem in chain drives).

Elastomeric teeth 78, are constructed so that the curvilinear outermost portions thereof have a longitudinal cross-sectional configuration which is constant across the transverse cross section of the belt which is substantially comprised of two circular arcs 80 and 82 of equal radius 84 and 86 crossing at point 88 on centerline 90 of the tooth cross section. The centers of curvature 92 and 94 of radii of the circular arcs 80 and 82 forming the sides of the tooth are located on line P that extends substantially parallel to the tensile member 70 in the longitudinal direction when the tensile member is linearly positioned as shown. The circular arcs extend from the point 88 to the line P. The centers of curvature for the right and left side of the tooth are displaced on opposite sides of the centerline 90 of the tooth 78 from the corresponding arcs by an amount equal to or less than 10% of the radii of curvature 84 and 86 of the circular arcs. The land area 89 between adjacent teeth 78 is a small straight section parallel to the line P connecting the ends of the tooth roots 74 and 76 adjacent to the tensile member 70. Line P is spaced from the land area by amount less than or equal to 40% of the total tooth depth which is a distance along line 90 between point 88 and the intersection of line 90 with an extension of the plane of the land area 89. Surfaces of the roots 74 and 76 of the belt teeth viewed on cross section are circular arcs having equal radii 96 and 98. The centers of curvature 100 and 102 of root radii 96 and 98 are located on a line Q situated between the land area 89 of the teeth and point 88 by a distance equal to or less than

the distance from the plane of the land area to the line P measured along the centerline 90 of the tooth 78. The arcs of the roots 74 and 76 begin at line Q and end at land area 89. When the centers of curvature 100 and 102 are located on line Q spaced from line P, the tooth arcs 80 and 82 and the respective adjacent root arcs 76 and 74 are connected by a straight line tangent to those arcs at the point of their intersection with lines P and Q respectively.

The radius of the curvature of the root of the belt tooth is selected so that a line drawn tangent to the belt tooth at the point where the tooth blends to the main portion of the tooth makes an angle of less than 30° with the centerline 90 of the tooth. The optimum angle would be approximately 5°. This is to prevent the belt teeth from jumping out of engagement with the pulley teeth. Further, the root radius of the belt teeth should be less than 95% of the tip radii of the pulley teeth so that when the belt is under weighted load there is limited contact between the belt and the regions of the root of the belt teeth and the tips of the pulley teeth thereby eliminating strain concentrations at the roots of the belt teeth. The optimum root radius is 82% of the tip radius.

The width of the belt tooth, as measured between the ends of the belt tooth roots which are closest to the tensile member, should be as small as possible to obtain a more uniform load across the entire belt tooth and the region of the belt tooth—tensile member interface.

The selection of the radii of curvature of the belt teeth should be such that the curvilinear contour of the outer end of the tooth proximally matches the contour of the half-order isochromatic fringe in the belt as more fully described in U.S. Patent 3,756,091 to Miller. It was found in Miller that a tooth shaped similarly to the half-order isochromatic fringe effectively transferred the force of the pulley to the belt tooth without concentrating the force within the belt tooth. The more even distribution of force within the belt tooth provides for long belt life with a minimum probability of tooth shear. This is particularly important for an escalator which requires higher horse power loads to safely and reliably transport escalator passengers.

Surprisingly, it was found that the belt teeth, which were designed to transfer load circumferentially, transferred the load linearly to the link teeth with the same attendant advantages. Load is transferred evenly across the belt teeth to the link without having the belt teeth jump out of engagement with the link teeth. Noise is reduced considerably and the ride is very smooth.

A modular drive is provided that has a long belt life and a smooth ride due to the cooplink teeth, and has a quiet ride and low maintenance requirements due to the cooperation between the substantially inextensible elastomeric belt and plastic link. The belt life is further enhanced by the minimal number of bends experienced by the belt. Cooperation among the belt, pulleys and links is further enhanced by the substantialy inextensible nature of the belt.

It should be understood that the invention is not limited to the particular embodiments shown and described herein, but that various changes and modifications may be made without departing from the spirit and scope of the invention as defined by the following claims.

CLAIMS

1. An escalator having steps comprising:
a motor;
a pair of pulleys driven by said motor, each pulley having a plurality of juxtaposed contoured teeth;
a series of connected links, each link having a plurality of juxtaposed contoured teeth, each link connecting to one of said steps; and
a flexible, substantially inextensible tensile belt having a first side and a second side, each of the first and second sides having a plurality of juxtaposed contoured teeth, the teeth on said first side being in arcuate contact with said contoured teeth of said pulleys and the teeth on said second side being in linear contact with said contoured teeth of said links.

2. The escalator of claim 1, wherein:
each of said contoured belt teeth has a cross-sectional contour which approximates a contour of the order of a one-half isochromatic fringe in the belt when the tooth is under load.

3. The escalator of claim 1 to 2, wherein said belt teeth are formed of:
an elastomeric material.

4. The escalator of claim 1, 2, or 3 wherein each said link comprises:
a plastic plate having said juxtaposed contoured teeth formed integrally therein;
a first plastic arm extending from one end of said plate;
a second plastic arm extending from an opposite end of said plate, said first and second arms being adapted to engage the respective other of said first and second arms of another link of said series of links and being adaptable to engage one of said steps;
means for reinforcing said plate and said first and second arms such that said link withstands a bending moment encountered as said link transfers a driving force from said motor and pulleys to said step.

5. The escalator of claim 4 wherein said plastic first and second arms are comprised of a highly lubricious plastic such that said first and second arms do not require lubrication while transferring said driving force.

plastic comprises an aromatic polyester.

7. A link for use in a series of connected links to transmit a driving force from a driving means to escalator steps comprising:

a plastic plate having a plurality of contoured teeth for engaging said driving means;

a first plastic arm extending from one end of said plate;

a second plastic arm extending from an opposite end of said plate, said first and second arms being adapted to engage the respective other of said first and second arms of another link to form said series of connected links and being adaptable to engage one of said escalator steps;

means for reinforcing said plate and said first and second arms such that said link withstands a bending movement encountered as said link transfers said driving force from said driving means to said steps.

8. The link of claim 7 wherein said plastic first and second arms are comprised of a highly lubricious plastic such that said first and second arms do not require lubrication while transferring said driving force.

9. The link of claim 7 or 8 wherein said plastic comprises an aromatic polyester.

10. The escalator of any of claims 1 to 6 or the link of any of claims 7 to 9 wherein said link teeth comprise:

tip portions connected by cavity portions, each tip portion having a longitudinal cross-sectional contour partially composed of two substantially circular arcs, said arcs having centers of curvature displaced from each other, the center of curvature of each arc being located on the same side of the center line of said tip portion as its respective arc, the outermost portion of each tooth tip joining the two arcs forming a line segment, the length of the line segment being from 6% to 33% of the width of the belt teeth, and the distance between the outermost portion of the link teeth cavities and the innermost portion of the link teeth cavities being less than the depth of the belt teeth which are not in contact with the link.

11. An escalator substantially as described with reference to the accompanying drawings.

12. A link for use in a series of connected links to transmit a driving force from a driving means to escalator steps substantially as described with reference to Figs. 1, 3 and 4 of the accompanying drawings.

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